Claims 1-9 (Canceled)

Claim 10 (Previously presented): The apparatus of claim 31, wherein the reflector layer has a thickness in the range of about 3 to about 30 nanometers.

Claim 11 (Canceled)

Claim 12 (Previously presented): The apparatus of claim 28, wherein the light source is a laser configured for emitting the transmitted light as collimated light.

Claim 13 (Previously presented): The apparatus of claim 12, wherein the transmitted light has a wavelength of about 850 nanometers and an intensity selected from the range of about 1 to about 3 microWatts.

Claim 14 (Withdrawn): An apparatus for use in measuring diffusible hydrogen concentrations in a selectable portion of a structure, comprising:

a housing having a first opening adapted for being operatively and selectively connected to a selected portion of the structure, whereby hydrogen evolving from the selected portion is captured within the housing; and

a hydrogen sensor mounted in the housing so as to be exposed to the captured evolving hydrogen from the selected portion, wherein the hydrogen sensor comprises material that changes optical properties based on concentration of the captured evolving hydrogen.

Claim 15 (Withdrawn): The apparatus of claim 14, wherein the housing defines a sample area on the selected portion of the structure and defines a sample volume adjacent the hydrogen sensor wherein the captured evolving hydrogen is sealably contained, and wherein the diffusible hydrogen concentrations of the selected portion of the structure are measurable based on the sample area, the sample volume, and the changes in the optical properties of the hydrogen sensor.

Claim 16 (Withdrawn): The apparatus of claim 15, further including an optical fiber for directing light to and away from the hydrogen sensor, the optical fiber being mounted within the housing with a first end adjacent the hydrogen sensor and a second end proximal to a second opening of the housing.

Claim 17 (Withdrawn): The apparatus of claim 16, further including a reflector mounted in the housing adjacent the first opening and interposed between the hydrogen sensor and the sample volume, wherein the reflector comprises a material that adsorbs and releases molecular hydrogen and that reflects light.

Claim 18 (Withdrawn): The apparatus of claim 17, further including a hydrogen monitoring assembly operably connected to the second end of the optical fiber and adapted for transmitting light to the second end of the optical fiber, for receiving a portion of the transmitted light that passes through the hydrogen sensor and is reflected by the reflector, and for determining a diffusible hydrogen concentration of the selected portion of the structure based on the received portion of the transmitted light.

Claim 19 (Previously presented): A method for measuring a diffusible hydrogen concentration in an object at a particular previous point in time, comprising:

    selecting a portion of the object from which to obtain a diffusible hydrogen concentration measurement;

    sealably mounting a hydrogen sensor assembly on the selected portion of the object, the sensor assembly including a housing that defines a sample area on the selected portion from which hydrogen is allowed to evolve and a predetermined sample volume in which the evolving hydrogen is captured, wherein the sensor assembly further includes a hydrogen sensor comprising a hydrogen-reactive material mounted within the housing adjacent the sample volume, said hydrogen-reactive material being of a type that has a physical property which changes as a function of hydrogen concentration in the sample volume;

allowing the hydrogen sensor to react with the captured evolving hydrogen for a sample time period that is at a sampling time subsequent to said previous point in time whereat the rate of hydrogen evolution is compatible with the sensing ability of the hydrogen reactive material;

measuring change in [[a]] the physical property of the hydrogen sensor over said sample time period;

correlating said change via a predetermined relationship between the physical property measured and concentration of hydrogen to obtain a rate of change of hydrogen in the sample volume during the sample period, which corresponds to hydrogen diffusivity rate from the object; and

determining the diffusible hydrogen concentration in the selected portion of the object at said particular previous point in time based on the rate of change in the physical property of the hydrogen sensor by correlating the rate of change in the physical property via a predetermined relationship between rate of change in the physical property to diffusible hydrogen concentration in the object.

Claim 20 (Previously presented): The method of claim 19, wherein the sample time period is in a range of 10 to 30 minutes.

Claim 21 (Previously presented): The method of claim 19, wherein the selected portion is a welded joint, and further including prior to the mounting, waiting a cooling time period after the welded joint is welded, and determining an initial diffusible hydrogen concentration in the welded joint by correlating the hydrogen diffusivity rate at the cooling time with a predetermined example slope from among a plurality of pre-determined example slopes of hydrogen diffusion curves for a plurality of example initial diffusible hydrogen concentrations at said cooling time period.

Claim 22 (Original): The method of claim 19, wherein the physical property is optical transmissivity of the hydrogen sensor and the sensor assembly further includes

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a reflector positioned within the housing so as to be interposed between the sample volume and the hydrogen sensor, the reflector being configured for reflecting light passing through the hydrogen sensor back through the hydrogen sensor.

Claim 23 (Original): The method of claim 22, further including operatively connecting a reflectance monitoring device including a light source and a light signal detector to the sensor assembly, and wherein the measuring includes operating the reflectance monitoring device to transmit a light signal from the light source to the hydrogen sensor and to receive a reflected portion of the light signal with the light signal detector.

Claim 24 (Original): The method of claim 23, further including connecting a signal analyzer to the light signal detector for receiving a signal from the light signal detector based on the received reflected portion, and wherein the calculating of the diffusible hydrogen concentration is completed in part by operating the signal analyzer to compare the signal from the light signal detector and the transmitted light signal from the light source.

Claim 25 (Original): The method of claim 19, further including calibrating the hydrogen sensor assembly to create calibrating information, and wherein the calculating of the diffusible hydrogen concentration is based on the calibrating information.

Claim 26 (Currently amended): The method of claim 2~~5~~6, the calibrating being completed prior to the mounting of the hydrogen sensor assembly based on measurements of the sample area and the sample volume and based on collected calibration testing information.

Claim 27 (Original): The method of claim 26, the calibrating being completed after the mounting of the hydrogen sensor on the object and including injecting a selected amount of hydrogen into the sample volume, allowing the selected amount of

hydrogen to react with the hydrogen sensor for a predetermined calibration time, and measuring the amount of change in the physical property of the hydrogen sensor.

Claim 28 (Previously presented): Diffusible hydrogen sensor apparatus for detecting initial diffusible hydrogen concentration in a solid metal object at an initial point in time, comprising:

a sensor housing with a sealing member attached thereto disposed to surround a leak proof predetermined sample area of the object;

the sensor housing having a predetermined sample volume within the housing adjacent [[to]] the sample area to define a leak proof sample chamber;

a hydrogen sensor with a sealed connection to the leak proof sample chamber;

the hydrogen sensor further comprising a layer of hydrogen-reactive chemochromic material in communication with the leak proof sample chamber;

a light source optically connected to the sensor housing to transmit light to the hydrogen sensor wherein the properties of light reflected from the layer of hydrogen-reactive chemochromic material varies as a function of hydrogen concentration in the leak proof sample chamber; and

a detector and signal analyzer connected to the sensor housing for receiving the reflected light from the layer of hydrogen-reactive chemochromic material wherein the reflected light is detected and analyzed by the signal analyzer to correlate the variations in the light input to quantities of hydrogen in the predetermined sample volume and to then correlate an increase in such quantities of hydrogen in the sample volume to a diffusivity rate of the hydrogen diffusing from the solid metal object, and for further correlation of the diffusivity rate to the initial diffusible hydrogen concentration in the solid metal object by correlation of the diffusivity rate to a plurality of example slopes of hydrogen diffusion curves for a plurality of example initial diffusible hydrogen concentrations that are predetermined for

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example solid metal objects and for sampling times after the initial point in time where the rate of hydrogen evolution is compatible with the sensitivity of the hydrogen reactive chemochromic material.

Claim 29 (Currently amended): The apparatus of claim 28 wherein the chemochromic material is~~being~~ selected from a group consisting of transition metal oxide, tungsten trioxide, molybdenum trioxide, yttrium dihydride, rare earth dihydride, or lanthanum dihydride~~.~~

Claim 30 (Previously presented): The apparatus of claim 29, wherein a reflective layer of catalytic material is added to the chemochromic material that adsorbs molecular hydrogen, converts the molecular hydrogen to atomic hydrogen, and release the atomic hydrogen into the hydrogen reactive chemochromic layer.

Claim 31 (Previously presented): The apparatus of claim 30 wherein the reflective layer of catalytic material is selected from a group consisting of palladium or platinum.

Claim 32-39 (Cancelled)

Claim 40 (Previously presented)   A method of subsequent determination of an initial volume of hydrogen per unit mass of metal that was present in a particular welded metal joint specimen when the particular welded metal joint specimen was welded, comprising:

 creating a set of example curves with slopes that are representative of respective diffusivity rates of hydrogen evolving from example welded metal joints as a function of time after welding for a plurality of respective example values of initial volumes of hydrogen per unit mass of metal in the example welded metal joints;

 determining an actual diffusivity rate of hydrogen evolving from the particular welded metal joint in a particular time period after welding by positioning and sealing a sample chamber with a sample opening on the

particular welded metal joint specimen so that hydrogen evolving from the particular welded metal joint specimen is captured in the chamber, and measuring in the time period a change of a parameter that is correlated to diffusivity rate of the hydrogen that evolves from the particular welded metal joint into the sample chamber; and

determining the initial volume of hydrogen per unit mass of metal that was present in the particular welded metal joint specimen when the particular welded metal joint specimen was welded by correlating the actual diffusivity rate in the particular time period after welding with the slopes of the example curves for the same time period, wherein said time period is short enough so that the actual diffusivity rate of the hydrogen evolution is compatible with measurements of the change of the parameter.

Claim 41 (Cancelled)

Claim 42 (Previously presented)   The method of claim 40, wherein the parameter is intensity of light that varies as a function of hydrogen concentration in the sample chamber.

Claim 43 (Previously presented)   The method of claim 42, wherein the change of intensity of light is correlated to the diffusivity rate of the hydrogen that evolves from the particular welded metal joint specimen into the sample chamber by calibrating the intensity of light parameter to specific concentrations of hydrogen, multiplying the concentrations of hydrogen by the volume of the sample chamber to correlate the light intensity parameter to volume of hydrogen in the sample chamber, and dividing changes in the volume of hydrogen in the sample chamber by the time in which such changes in the volume of hydrogen in the sample chamber occur to correlate the measured changes of intensity of light parameter to actual diffusivity rates of hydrogen evolving from the particular welded metal joint specimen into the sample chamber.

Claim 44 (Previously presented)   The method of claim 43, including positioning a chemochromic material in the sample chamber, said chemochromic material having a characteristic light transmissivity that varies in response to exposure to hydrogen, directing a light beam to pass through the chemochromic material at least once, and measuring the parameter as loss of intensity of the beam of light upon passing through the chemochromic material.

Claim 45 (Previously presented)   The method of claim 40, wherein the parameter is a property of an electric circuit that varies as a function of hydrogen concentration in the sample chamber.

Claim 46 (Previously presented)   The method of claim 45, wherein the parameter is electric current that varies as a function of hydrogen concentration in the sample chamber.

Claim 47 (Previously presented)   The method of claim 46, including positioning a material in the sample chamber that varies in electrical resistivity in response to exposure to hydrogen, applying a voltage across the material, and measuring the electric current that flows through the material.

Claim 48 (Previously presented)   The method of claim 40, including creating the set of example curves by welding a sample welded metal joint, determining the diffusivity rate of hydrogen evolving from the sample welded metal joint by measuring the parameter in a sample time period after the sample is welded and plotting the measurements of the parameter as a function of time to obtain an actual response slope that represents the diffusivity rate, deriving an equation that closely correlates in shape and slope to the plot of the measurements of the parameter as a function of time, and developing the set of example curves from the equation for a plurality of different initial diffusion hydrogen concentrations as a function of time.

Claim 49 (Previously presented)   The method of claim 48, including deriving the equation from an error function.

Claim 50 (Previously presented)   A method of subsequent determination of an initial diffusible hydrogen concentration that was present in a particular metal specimen at a particular previous point in time, comprising:

     creating a set of example curves with slopes that are representative of respective diffusivity rates of hydrogen evolving from example metal specimens as a function of time after said particular previous point in time for a plurality of respective example values of initial diffusible hydrogen concentrations in the example metal specimens;

     determining an actual diffusivity rate of hydrogen evolving from the particular metal specimen in a particular time period after said particular previous point in time by positioning and sealing a sample chamber with a sample opening on the particular metal specimen so that hydrogen evolving from the particular metal specimen is captured in the chamber, and measuring in the time period a change of a parameter that is correlated to diffusivity rate of the hydrogen that evolves from the particular metal specimen into the sample chamber; and

     determining the initial diffusible hydrogen concentration that was present in the particular metal specimen at said particular previous point in time by correlating the actual diffusivity rate in said particular time period after said particular previous point in time with the slopes of the example curves for the same time period, wherein said time period is within a short enough time after said particular previous point in time so that the actual diffusivity rate of the hydrogen evolution is compatible with ability to provide the measurements of the change of the parameter.

Claim 51 (Previously presented)   The method of claim 50, wherein the parameter is intensity of light that varies as a function of hydrogen concentration in the sample chamber.

Claim 52 (Previously presented)   The method of claim 51, wherein the change of intensity of light is correlated to the diffusivity rate of the hydrogen that evolves from the particular metal specimen into the sample chamber by calibrating the intensity of light parameter to specific concentrations of hydrogen, multiplying the concentrations of hydrogen by the volume of the sample chamber to correlate the light intensity parameter to volume of hydrogen in the sample chamber, and dividing changes in the volume of hydrogen in the sample chamber by the time in which such changes in the volume of hydrogen in the sample chamber occur to correlate the measured changes of intensity of light parameter to actual diffusivity rates of hydrogen evolving from the particular metal specimen into the sample chamber.

Claim 53 (Previously presented)   The method of claim 52, including positioning a chemochromic material in the sample chamber, said chemochromic material having a characteristic light transmissivity that varies in response to exposure to hydrogen, directing a light beam to pass through the chemochromic material at least once, and measuring the parameter as loss of intensity of the beam of light upon passing through the chemochromic material.

Claim 54 (Previously presented)   The method of claim 50, wherein the parameter is a property of an electric circuit that varies as a function of hydrogen concentration in the sample chamber.

Claim 55 (Previously presented)   The method of claim 54, wherein the parameter is electric current that varies as a function of hydrogen concentration in the sample chamber.

Claim 56 (Previously presented)   The method of claim 55, including positioning a material in the sample chamber that varies in electrical resistivity in response to exposure to hydrogen, applying a voltage across the material, and measuring the electric current that flows through the material.

Claim 57 (Previously presented)   The method of claim 50, including creating the set of example curves by providing a sample metal specimen with an example initial diffusible hydrogen concentration at a particular previous point in time, determining the diffusivity rate of hydrogen evolving from the sample metal specimen by measuring the parameter in a sample time period after the particular previous point in time and plotting the measurements of the parameter as a function of time to obtain an actual response slope that represents the diffusivity rate, deriving an equation that closely correlates in shape and slope to the plot of the measurements of the parameter as a function of time, and developing the set of example curves from the equation for a plurality of different initial diffusion hydrogen concentrations as a function of time.

Claim 58 (Previously presented)   The method of claim 57, including deriving the equation from an error function.

Claim 59 (Previously presented)   Apparatus for subsequently determining an initial diffusible hydrogen concentration that was present in a metal object at a previous point in time, comprising:

  a sampling chamber of a known quantitative volume with an opening that is sealably mountable on the object;

  a signal analyzer which correlates the signal changes to diffusivity rates of hydrogen evolving from the metal object based on the known quantitative volume of the sampling chamber and the hydrogen concentrations in the sampling chamber as indicated by the signals, and which produces an output that is indicative of the initial diffusible hydrogen concentration that was present in the metal object at the previous point in time by correlating the diffusivity rate to slopes of example curves of hydrogen diffusion from example metal specimens at times subsequent to example initial diffusion hydrogen concentrations that correlate with said previous point in time and where the hydrogen evolution is compatible with the sensitivity of the hydrogen sensor.

Claim 60 (New)   A method of subsequent determination of an initial diffusible hydrogen concentration in a particular weld of a particular metal, comprising:

creating a set of example curve slopes that are representative of respective diffusivity rates of hydrogen evolving from a plurality of example welds of the same particular metal at a subsequent time after welding, which correlate respectively to a plurality of respective example values of initial diffusible hydrogen concentration in the example welds;

generating a curve slope that is indicative of an actual diffusivity rate of hydrogen evolving from the particular weld at a particular time after welding the particular weld that corresponds to said subsequent time by positioning and sealing a sample chamber with a sample opening on the particular weld so that hydrogen evolving from the particular weld is captured in the sample chamber, and measuring, at the particular time after welding, a change of a parameter that is correlated to diffusivity rate of the hydrogen that evolves from the particular weld into the sample chamber; and

with the set of example curve slopes, correlating the curve slope that is indicative of the actual diffusivity rate of the particular weld to the example curve slopes to determine from the example curve slopes the initial diffusible hydrogen concentration that correlates to the curve slope that is indicative of the actual diffusivity rate of the particular weld.

Claim 61 (New)   The method of claim 60, wherein the parameter is intensity of light that varies as a function of hydrogen concentration in the sample chamber.

Claim 62 (New)   The method of claim 60, wherein the parameter is a property of an electric circuit that varies as a function of hydrogen concentration in the sample chamber.

Claim 63 (New)   The method of claim 60, including creating the set of example curve slopes empirically by generating a plurality of curve slopes that are indicative of diffusivity rates of hydrogen evolving respectively from a plurality of example

welds at a particular time after welding, determining the initial diffusible hydrogen
concentrations in respective duplicates of the example welds by standard American
Welding Society protocol, and ascribing those respective initial diffusible hydrogen
concentrations to the respective curve slopes.

Claim 64 (New)   The method of claim 63, including creating additional example
curve slopes theoretically by formulating parameters for a diffusion equation form of
an error function to conform a plurality of curve slopes obtained with the diffusion
equation form of the error function to the example curve slopes that are created
empirically and then calculating the additional example curve slopes using the
diffusion equation and formulated parameters with varying values for the initial
diffusible hydrogen concentration parameter.

Claim 65 (New)   A method of determining an actual diffusivity rate of diffusible
hydrogen evolving from a sample area of a metal specimen, comprising:

    positioning and sealing a sample chamber with a sample opening on the
metal specimen to define the sample area and so that hydrogen evolving from
the metal specimen in the sample area is captured in the sample chamber;

    allowing hydrogen to evolve from the sample area of the metal
specimen for a sample time period;

    measuring a change of a parameter that is indicative of a change in
hydrogen concentration in the sample chamber during the sample time period;

    determining the change in hydrogen concentration in the sample
volume by correlation with a quantitative relationship between the parameter
and hydrogen concentration;

    multiplying the change in hydrogen concentration by the volume of the
sample chamber to determine volume of hydrogen evolved from the sample
area into the sample chamber during the sample period; and

    dividing the volume of hydrogen evolved from the sample area by the
sample time to determine the hydrogen diffusion rate from the sample area.

Claim 66 (New)   The method of claim 65, wherein the parameter is intensity of light that varies as a function of hydrogen concentration in the sample chamber.

Claim 67 (New)   The method of claim 66, including positioning a chemochromic material in the sample chamber, said chemochromic material having a characteristic light transmissivity that varies in response to exposure to hydrogen, directing a light beam to pass through the chemochromic material at least once, and measuring the parameter as loss of intensity of beam of light upon passing through the chemochromic material.

Claim 68 (New)   The method of claim 65, wherein the parameter is a property of an electric circuit that varies as a function of hydrogen concentration in the sample chamber.

Claim 69 (New)   The method of claim 68, wherein the parameter is electric current that varies as a function of hydrogen concentration.

Claim 70 (New)   The method of claim 69, including positioning a material in the sample chamber that varies in electrical resistivity in response to exposure to hydrogen, applying a voltage across the material, and measuring the electric current that flows through the material.